Instrument Response Studies

Agenda

- Overarching Approach & Strategy
- Classification Trees
- Sorting out Energies
- PSF Analysis
- Background Rejection
- Assessment

Overarching Approach & Strategy

A 3 Stage Approach

1. Energy determination - Foundational to what follows
2. Evaluate PSF's - Background will be suppressed
3. Reject the Background - The hard part

Statistical Tools: Classification Trees & Regression Trees

A Brief History of Resolution & Rejection

Preparing for DC1 is a LARGE TASK

- Not likely to get right the 1st, or the 2nd, or the 3rd, or.... time!

1st Time: April-May
Discover Mult-scattering in G4 "too good to believe!"
Took till end of June to fix!

2nd Time: July (SAS Workshop)
OOPS! The ACD geometry!

3rd Time: July-August
Where did all the Run Numbers go?

4th Time: August
Will Bill never stop changing variable - well at least
he shouldn't make so many coding errors! Steve's variables added.

5th Time: August-September
Data of the day! But its certainly not "The rest of the story!"

6th Time: .... IS A CHARM!

Classification Tree Primer

Origin: Social Sciences - 1963

How a CT works is simple:

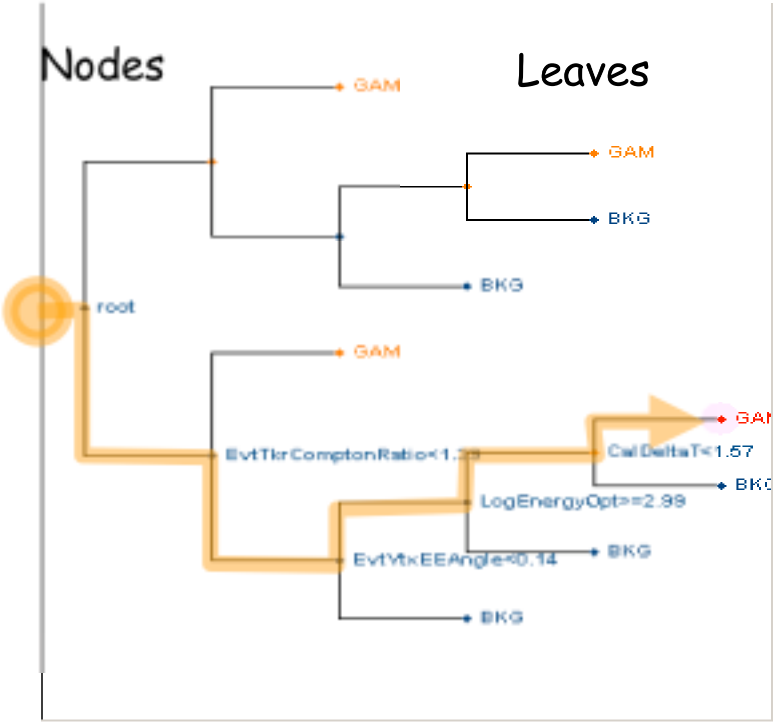
A series of "cuts" parse the data into a "tree" like structure, where final nodes (leaves) are "pure"

A "traditional analysis" is just ONE path through such a tree.

Tree are *much* more efficient!

Mechanism of tree generation less subject to "investigator basis."

A Simple Classification Tree



STATISTICALLY HONEST!

Input Data for Training and Testing

"Tree Production" automated by using "Training Samples" where the results are *a priori* known

All-Gammas (AG): 18 MeV < E_γ < 18 GeV
1/E Spectrum
-1 < cos(θ) < 0 (2π str)
$A_{GEN} = 6\ m^2$

AG Total: 3/4 x 10^6 Events

CAL -Training	25%
PSF -Training	50%
BKG -Training/Testing	25%

Background Events(BGEs): 0: Orbit Ave CHIME
1: Albedo Protons
2: Albedo γs
3: Cosmic e^-
4: Albedo e^+ & e^-

BKG Total: . 9 x 50 x 10^6 Events

BKG -Training	50%
BKG -Testing	50%

$A_{GEN} = 6\ m^2$

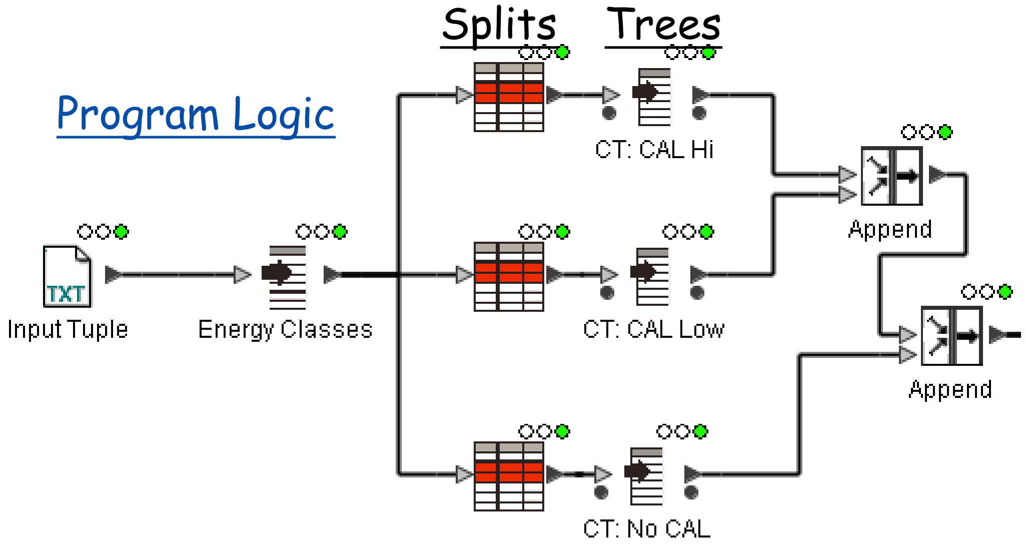
Energy Filtering

Problem: The large gaps in the CAL and the thick layers of the Tracker compromise the energy determination.

Strategy: Identify poorly measured events and eliminate them.

Technique: Split events into classes and for each class use a Classification Tree to determine the well-measured events.

Program Logic



Energy Class Definitions

CAL-Hi: CalEnergySum > 100 MeV
CalTotRLn > 2

CAL-Low: CalEnergySum < 100 MeV
CalEnergySum > 5 MeV
CalTotRLn > 2

No-CAL: CalEnergySum < 5 MeV or
CalTotRLn < 2

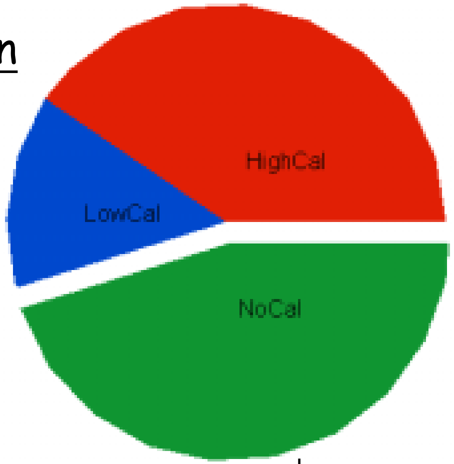
Energy Filtering (2)

Energy Class Breakdown

CAL-Hi: 41%

CAL-Low: 14%

No-CAL: 45%



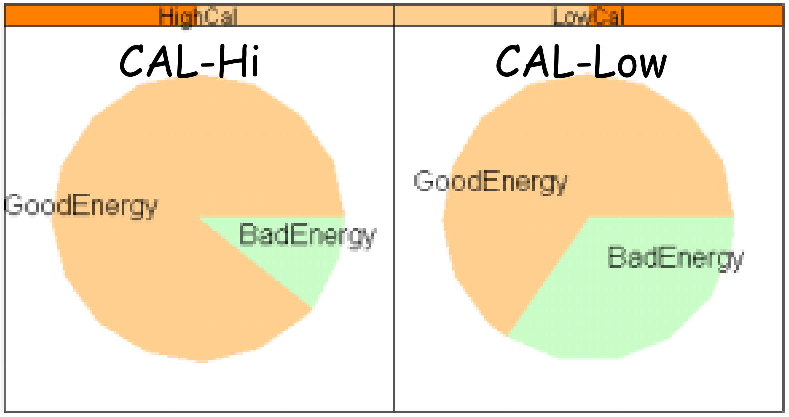
The No-CAL are presently not analyzed.

These will need to be addressed in the future as it constitutes the largest Energy Event Class and could greatly improve the transient response

CT Energy Classes: "GoodEnergy" = $\left|\frac{\text{CalEnergySumOpt} - \text{McEnergy}}{\text{McEnergy}}\right| < .35$ $(\sigma_{\text{Energy}} < 35\%)$

"GoodEnergy" / "BadEnergy"

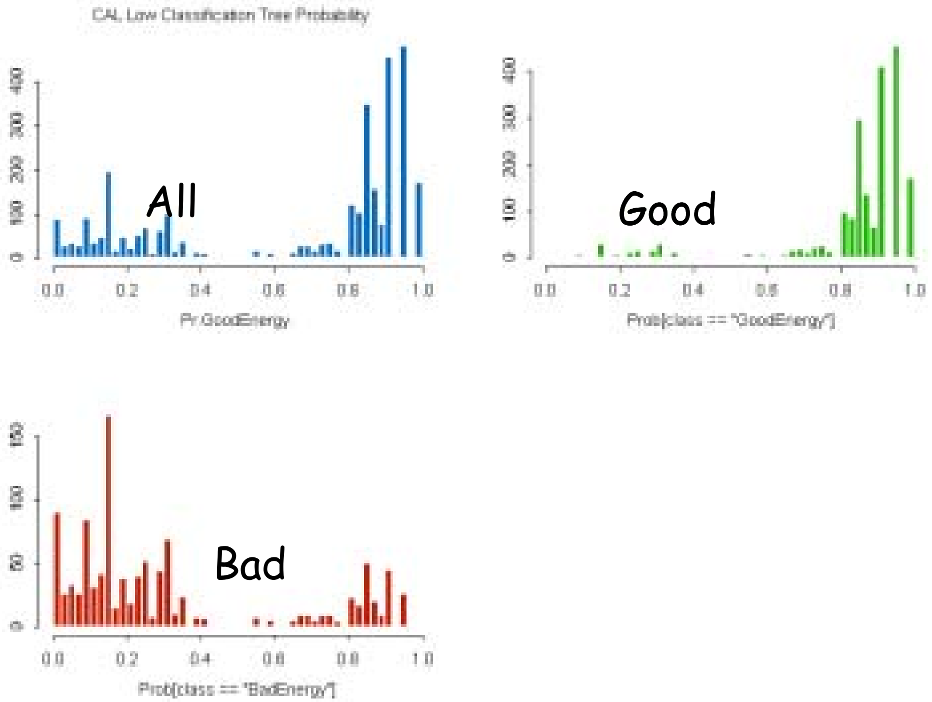
Event Breakdown by Energy Class



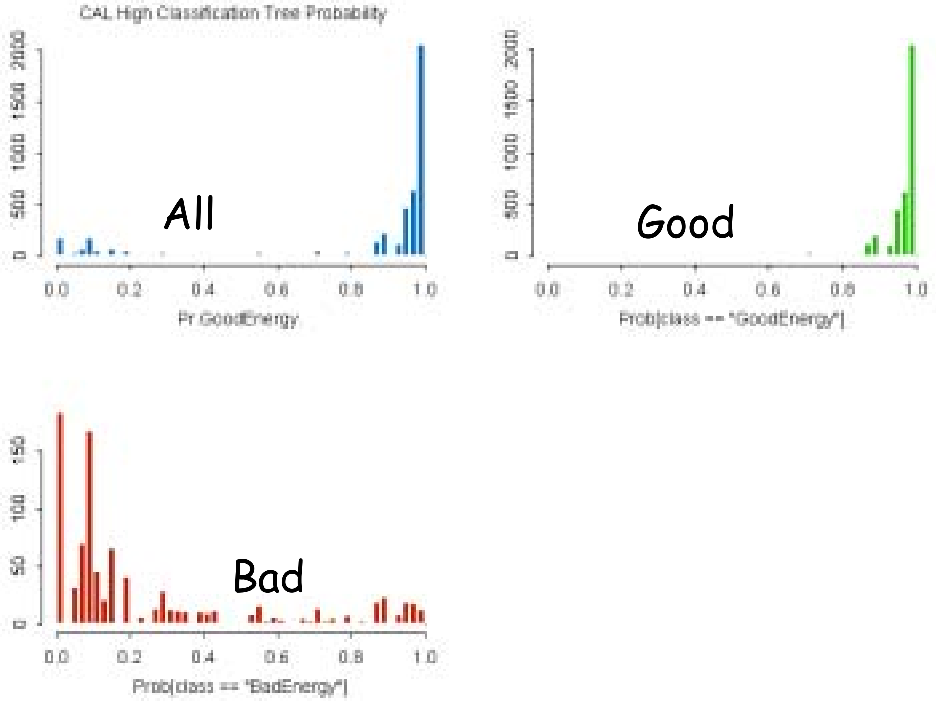
Energy Filtering (3)

All available variables bearing on the quality of the energy determination are made available to "train"

CAL-Low CT Probabilities

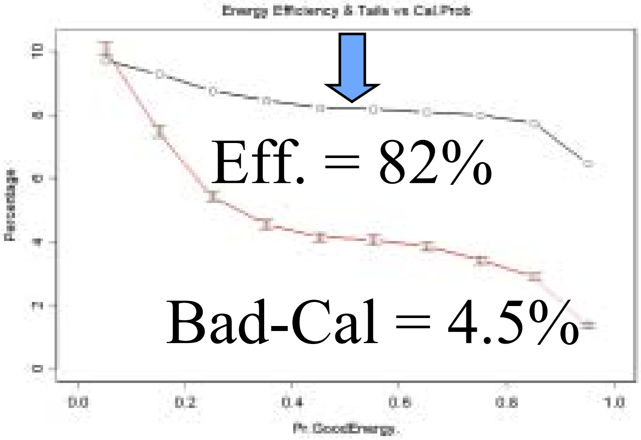


CAL-High CT Probabilities



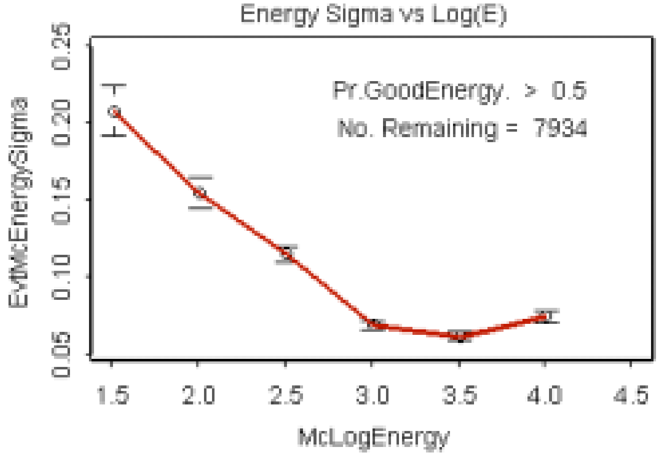
Energy Filtering (4)

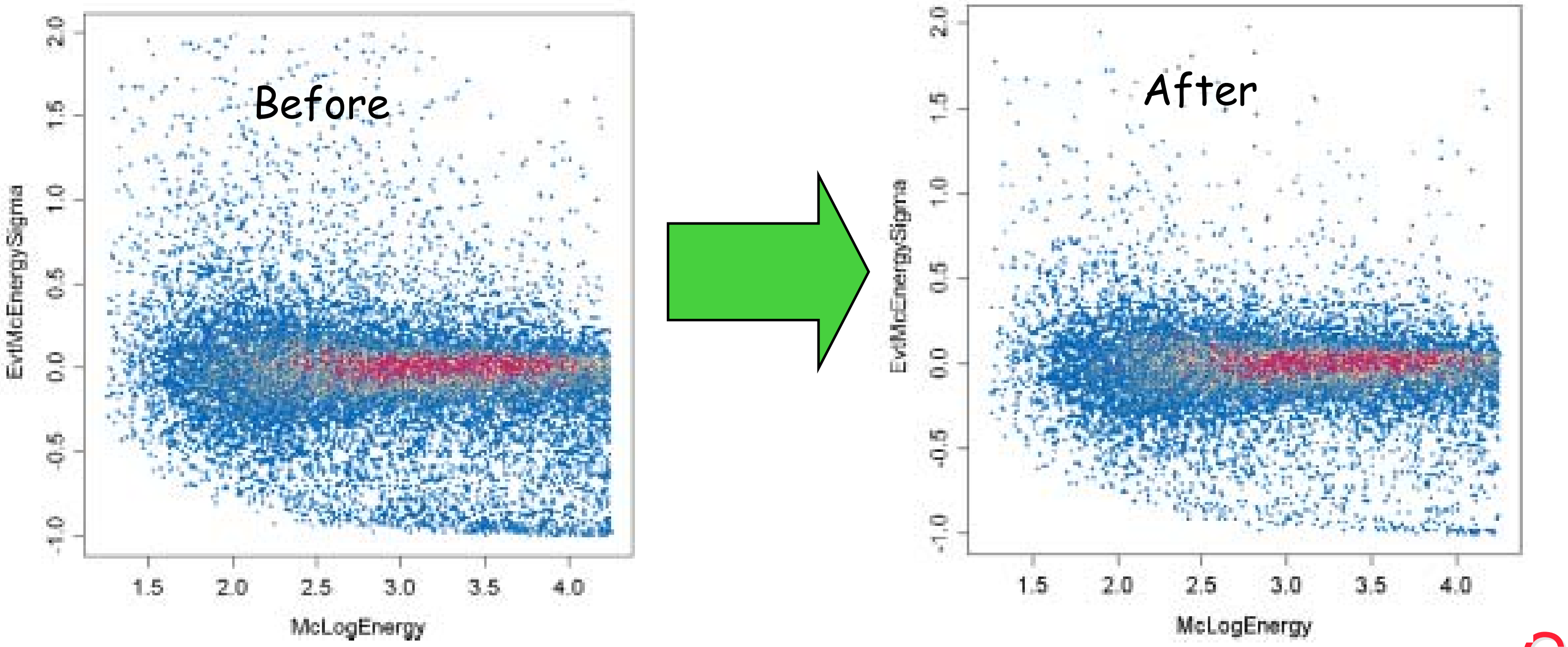
Cut:
Cal.Prob > .50



Eff. = 82%

Bad-Cal = 4.5%



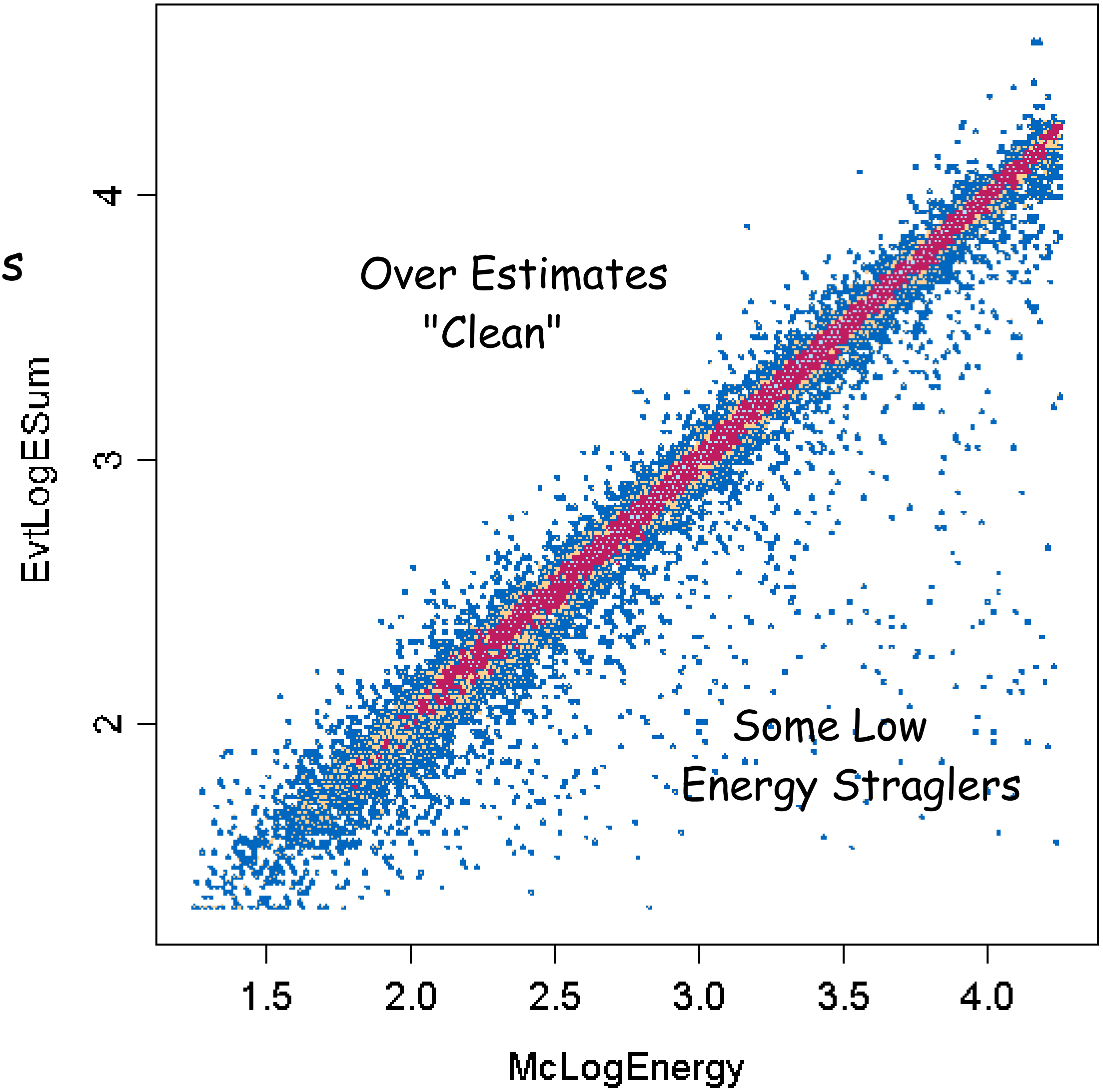


Energy Filtering (5)

The Results:

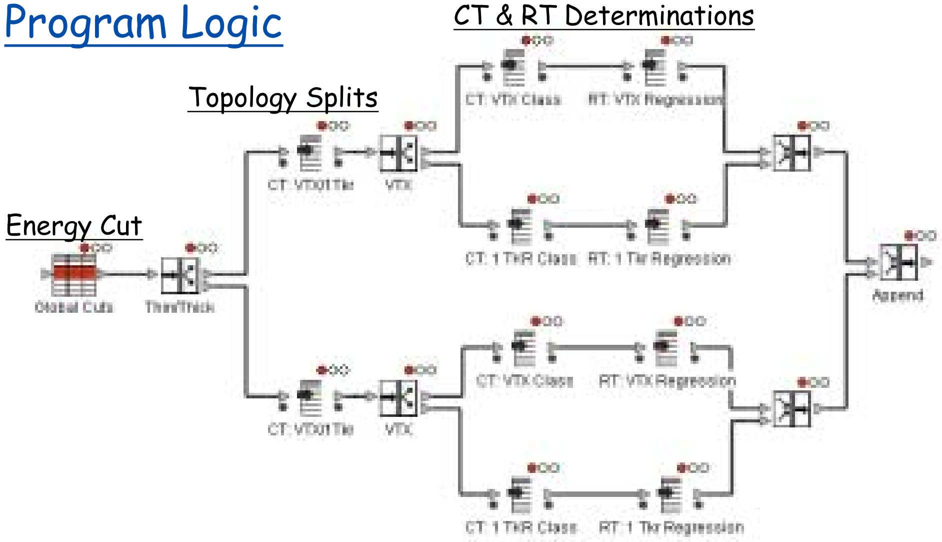
Cut more severe as events near Instrument Axis

We can use this for SCIENCE!



PSF Filtering

Program Logic



Global Cuts:

1) Cal.Prob > .50 (-18%)

Cleaning Cuts Applied to CT Training

2)EvtTkr1EChisq < 7.5 &
EvtTkr1EFirstChisq < 10. &
EvtTkr2EChisq < 10. &
EvtTkr2EFirstChisq < 10 (-5.6%)

TOTAL LOSS: -22.5% (Training)
-18% (Analysis)

Thin / Thick Split: Best Track originates in Thin / Thick Radiators
48% Thin / 52% Thick

VTX / 1Tkr Split: Use CT to determine whether or not to use Recon VTX Solution

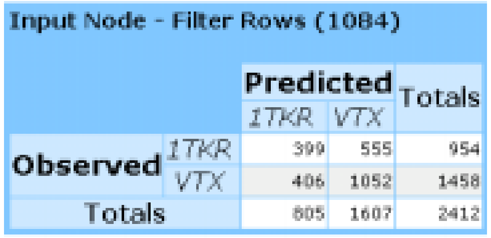
1 CT & 1 RT Used for each of the 4 PSF Classes: CT used to kill long tail
RT used to sharpen CORE resolution

PSF Filtering: VTX/1Tkr Split

Only events with a VTX solution are considered (VtxAngle > 0)

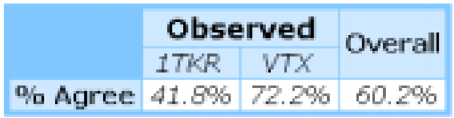
Using MC Truth, the best solution is determined (for CT Training)

Mariginal Improvement:
Purity (Before/After) 60% / 66%
(See Discussion at end of talk)

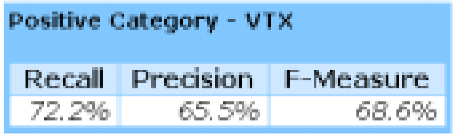


Input Node - Filter Rows (1084)

		Predicted		Totals
		1TKR	VTX	
Observed	1TKR	399	555	954
	VTX	406	1052	1458
Totals		805	1607	2412

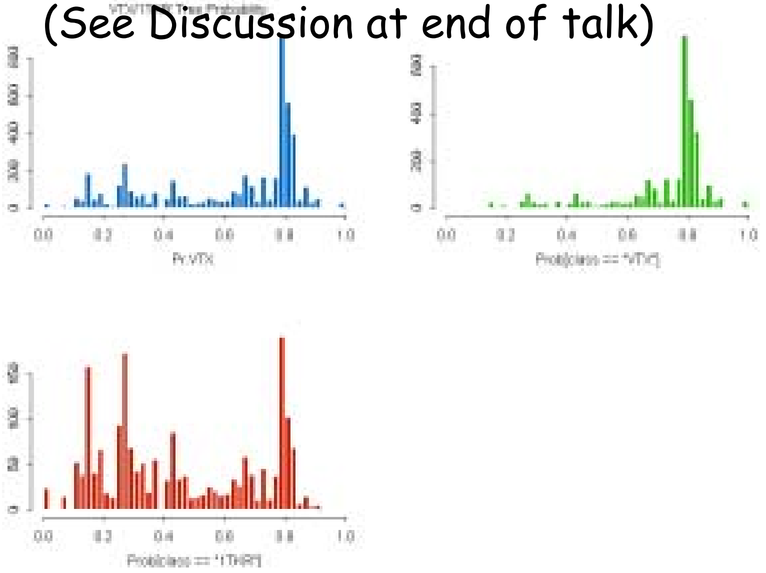


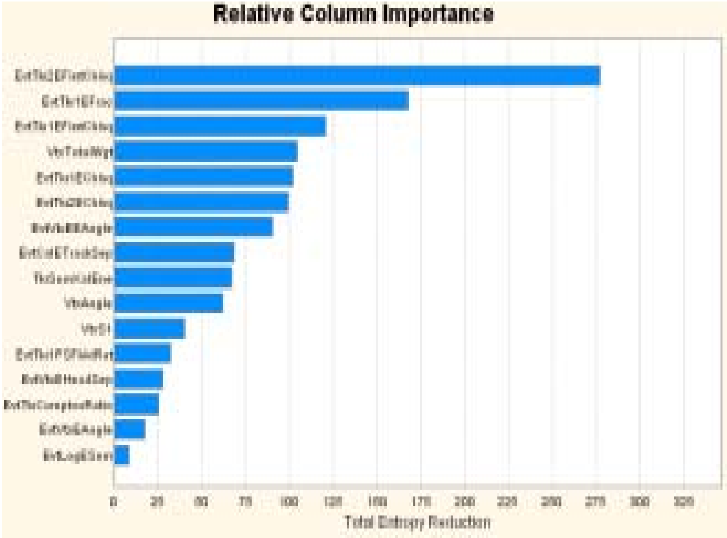
	Observed		Overall
	1TKR	VTX	
% Agree	41.8%	72.2%	60.2%



Positive Category - VTX

Recall	Precision	F-Measure
72.2%	65.5%	68.6%

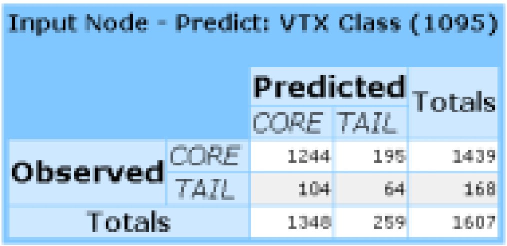




PSF Tails

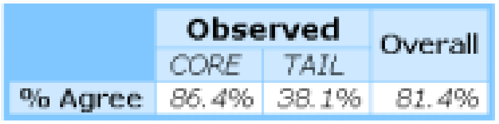
"Tail" Events defined as being 2.3 x *PSF Model* or worse.

Improvement:
38% of the "Tail" is eliminated at expense of 13.5% of the "Core"

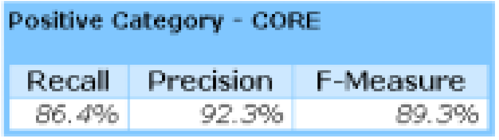


Input Node - Predict: VTX Class (1095)

		Predicted		Totals
		CORE	TAIL	
Observed	CORE	1244	195	1439
	TAIL	104	64	168
Totals		1348	259	1607

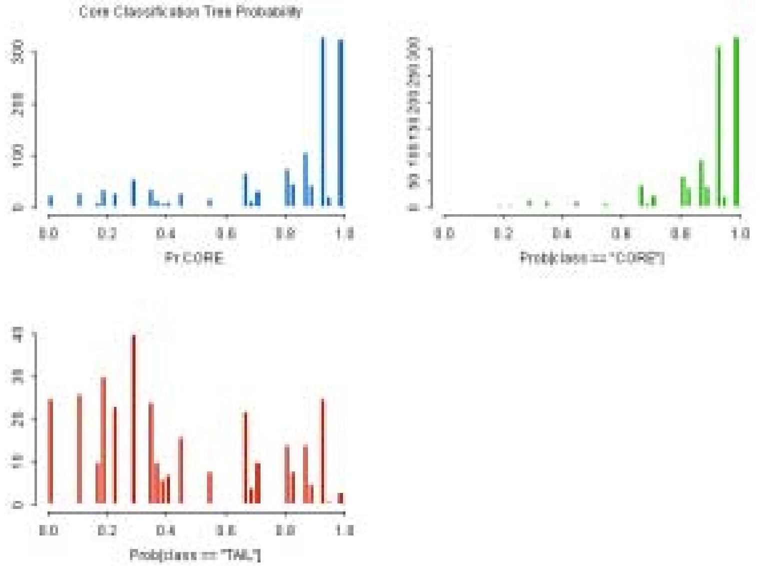


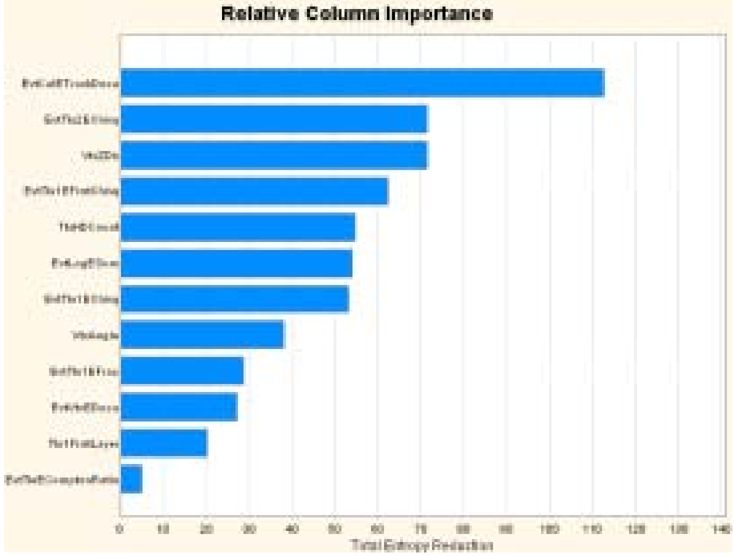
	Observed		Overall
	CORE	TAIL	
% Agree	86.4%	38.1%	81.4%



Positive Category - CORE

Recall	Precision	F-Measure
86.4%	92.3%	89.3%





PSF CORE

Tool: Regression Tree (Similar to CT)
Matches deviations rather then
class types.

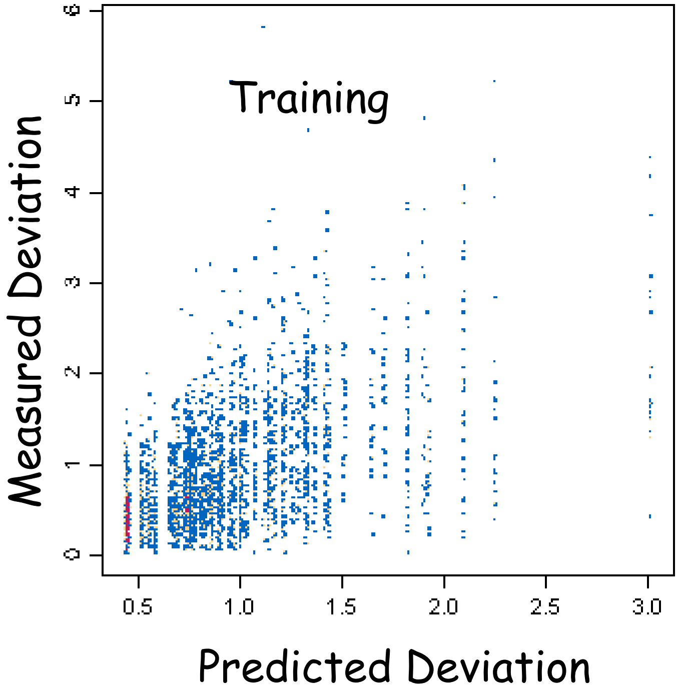
Event-by-Event PSF Error

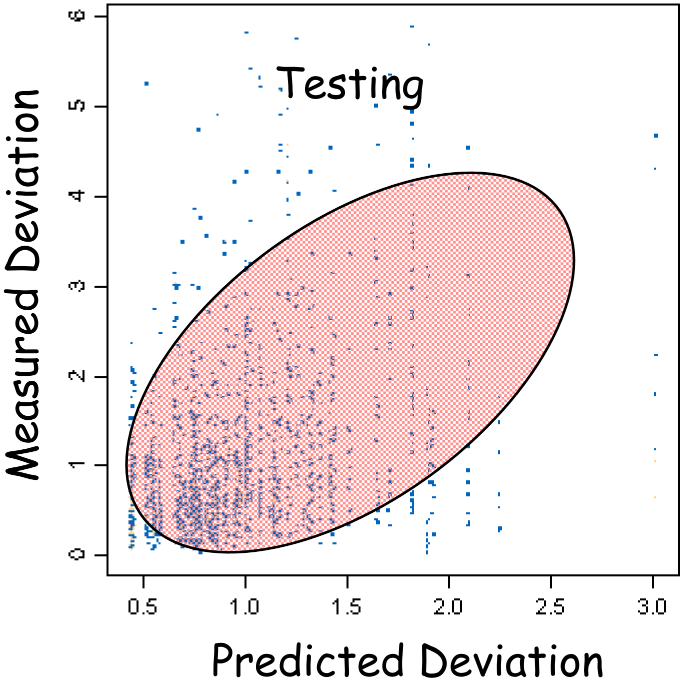
Energy Compensated by: $1/E_{Meas}^{.8}$

Collapse All PSF's onto one.

Normalization: 1 = PSF(68) Sci. Req.

Event Starvation VERY APPARENT!





PSF Summary

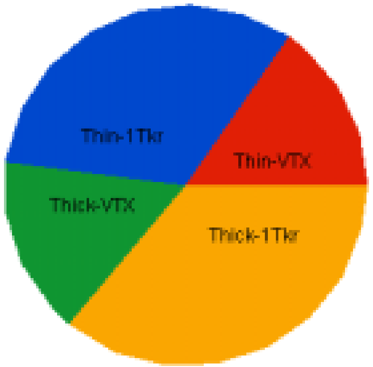
PSF Class Breakdown:

Thin-VTX: 15.3%

Thin-1Tkr: 32.7%

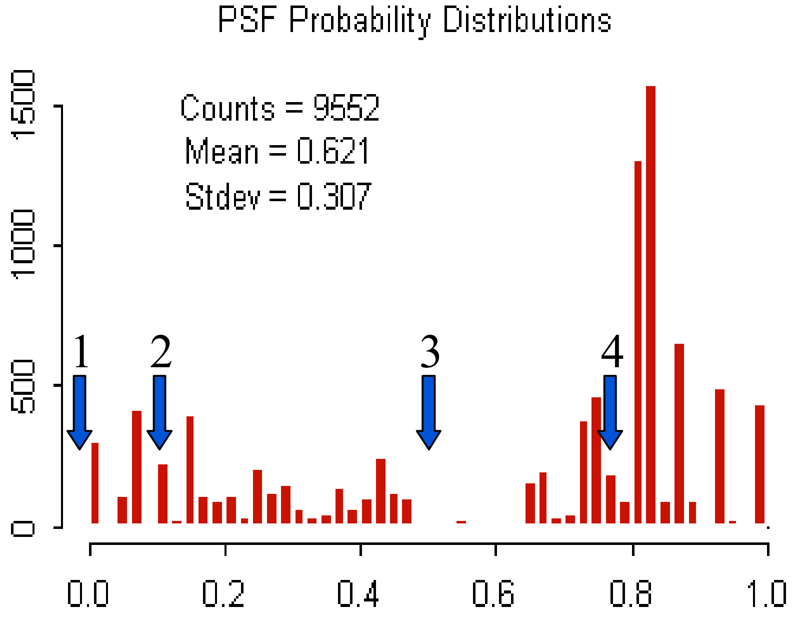
Thick-VTX: 15.9%

Thick-1Tkr: 36.0%

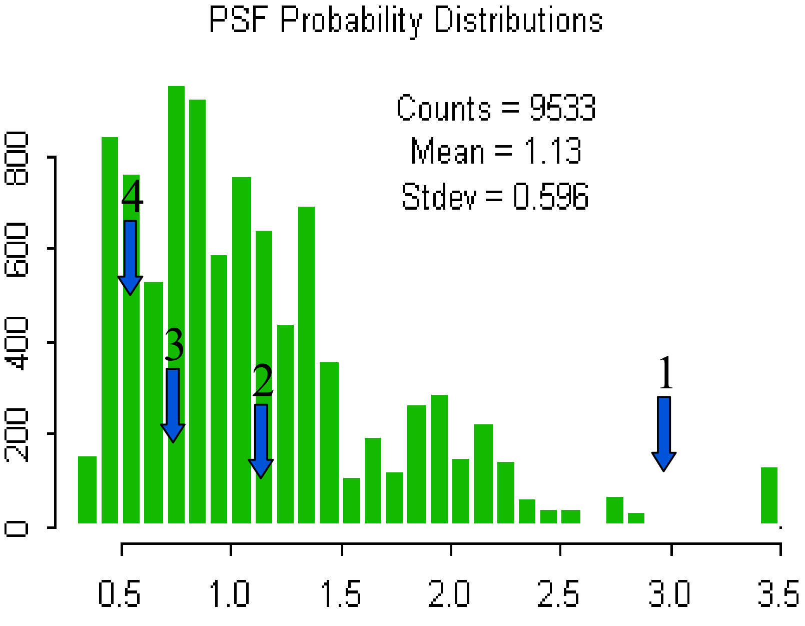


PSF Clean-up Cuts:

Matrix of 4x4 PSF Plots vs Log(E) examined



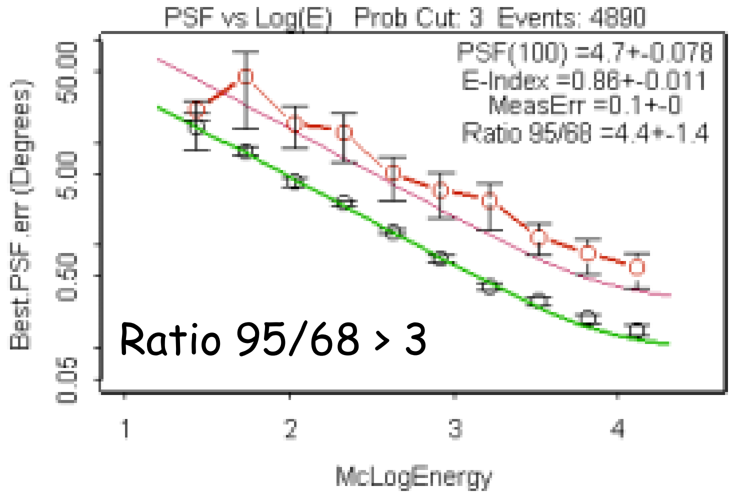
Core Cut: Limit PSF tails



Pred. PSF: Sharpen PSF

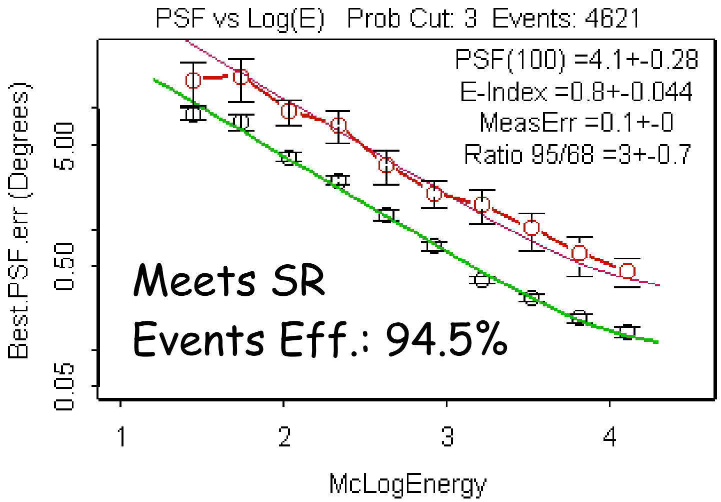
Thin PSF's - Integrated over FoV
4 Combinations of Cuts *(CORE/Pred)*

Cuts: 1/1



Ratio 95/68 > 3

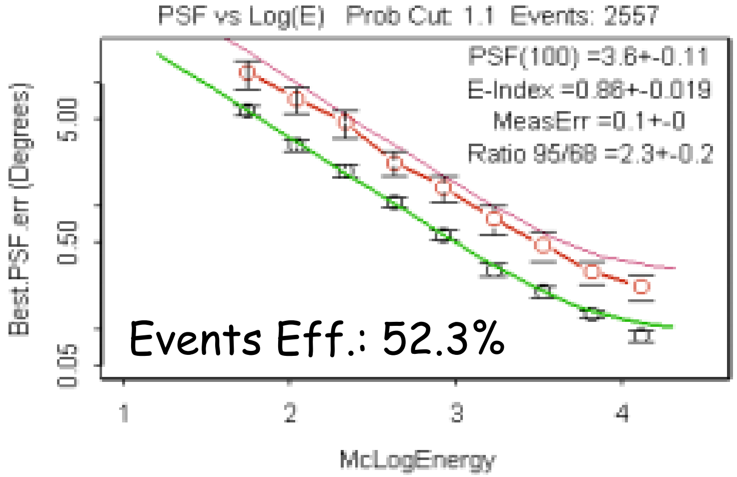
Cuts: 2/1



Meets SR

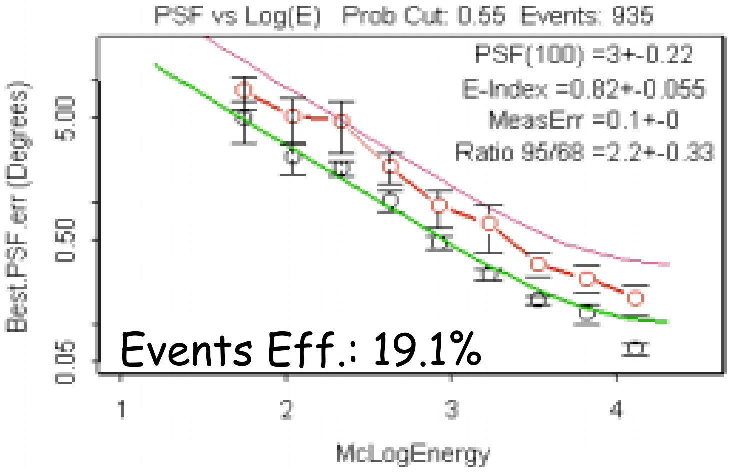
Events Eff.: 94.5%

Cuts: 3/2



Events Eff.: 52.3%

Cuts: 3/4



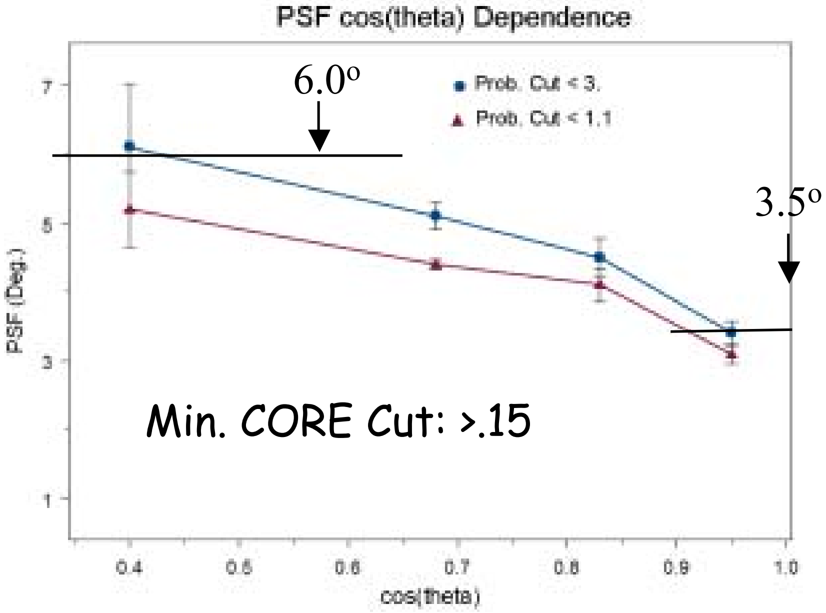
Events Eff.: 19.1%

PSF Summary - Minimum CORE Cut

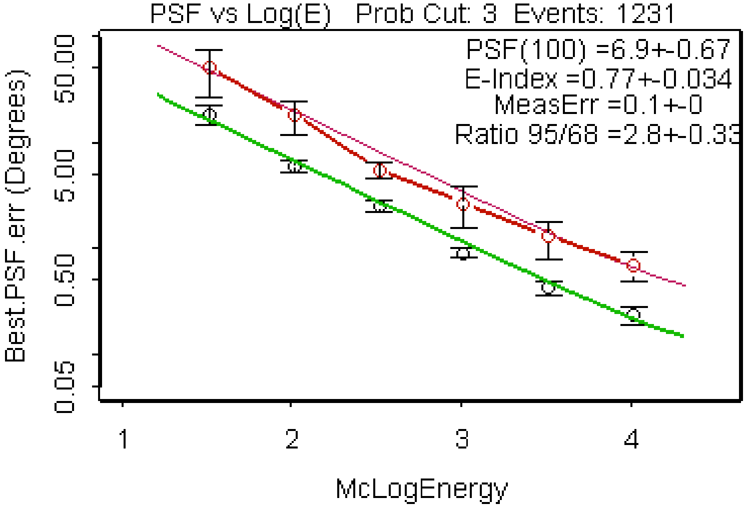
PSFs given prior to Background Rejection due to lack of statistics

Background rejection does not change conclusions.

Limited statistics don't allow for good determination of PSF vs cos(θ) for tight cuts



Min. CORE Cut: >.15



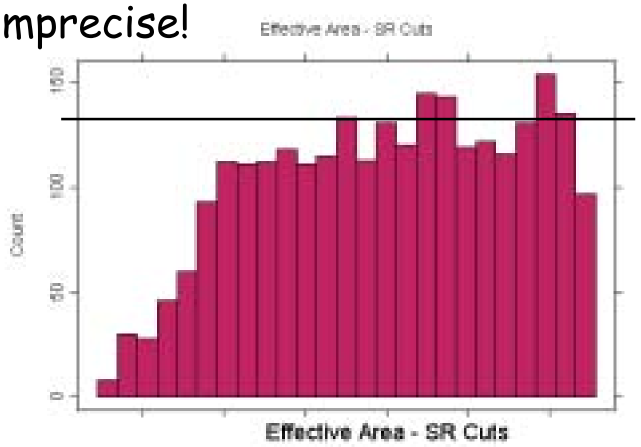
Thick Radiator PSF

PSF(Thick) = 2 x PSF(Thin)

CORE Cut and Pred. CORE are adjusted to have similar effects as for Thin Radiators

A_{eff} Summary - Minimum CORE Cut

Lack of events makes determination imprecise!



135/bin
asymptotic

Effective Area On Axis (E_γ > 3 GeV)

$A_{eff} = N_{Obs}/N_{Gen}$ x 6 x 1.3

A_{eff} = 2603/18750 x 7.8

A_{eff} = 1.1 m^2

Light Gathering Power (E_γ > 3 GeV)

A_{eff} x $\Delta\Omega = N_{Obs}/N_{Gen}$ x 6 x 2π x 1.27

A_{eff} x $\Delta\Omega$ = 9877/187500 x 37.7 x 1.27

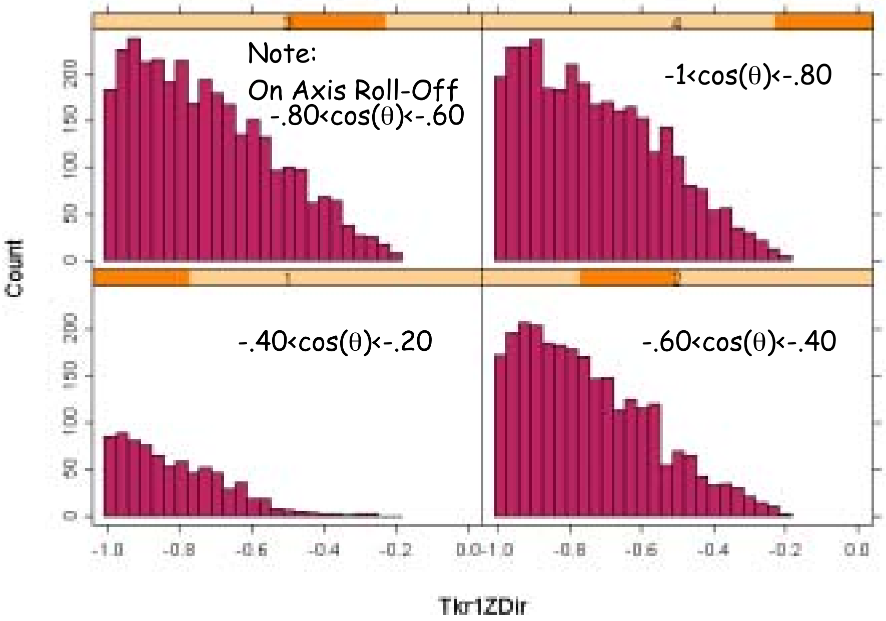
A_{eff} x $\Delta\Omega$ = 2.5 m^2-str

Angular Dependence

~ Linear in $\cos(\theta)$

At low energy FoV is truncated

Slight roll-over near axis due to CAL inefficiency caused by inter-tower gaps



Note:
On Axis Roll-Off
-.80<cos(θ)<-.60

-1<cos(θ)<-.80

-.40<cos(θ)<-.20

-.60<cos(θ)<-.40

Background Rejection

Pre-Analysis Filtering

Done to reduce data volume

Require at least 1 Reconstructed Track

Require AcdActiveDist < -20 mm
(AcdActiveDist defined to be distance to
edge of nearest hit Acd Tile. Values < 0
indicate projected track falls
OUTSIDE of hit tile area.)

Note: This has a built in Energy Dependence!

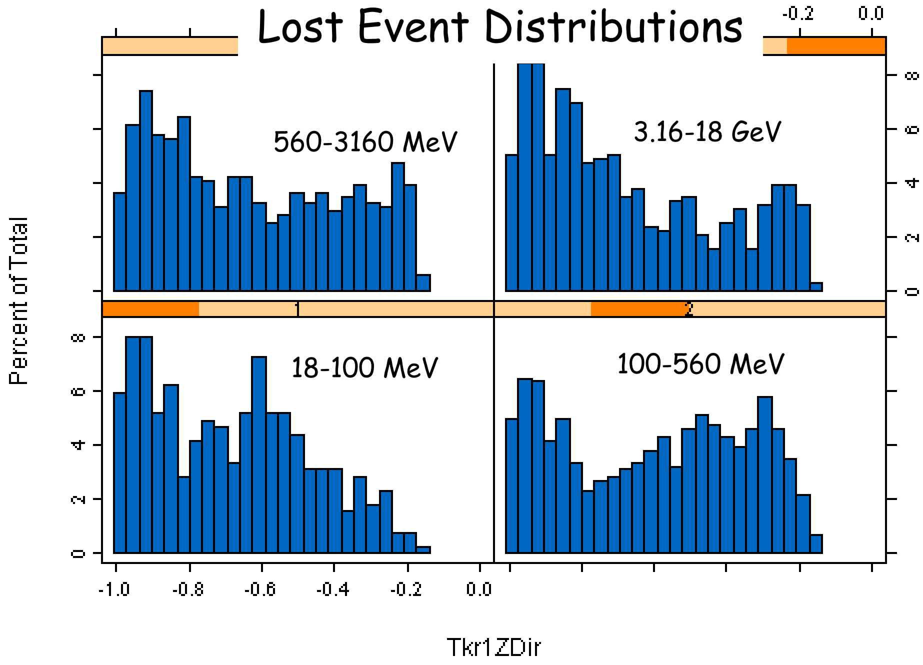
Generated:	50×10^6
Lost 10% from failed jobs:	45×10^6
Number of Triggers:	$\sim 18.5 \times 10^6$
Number left after pre-filter:	$.73 \times 10^6$

First Analysis Cut:

Require "GoodCal" Energy

Results in 18% loss in γ Events

Distribution of Event Loss in cos(θ)



Background Event Efficiency: 12.2%

BGE Left: 89.3×10^3

BGE Trigger Reduction Factor: ~200

Background Rejection Event Files

BGE sample divided in 2:

50% Training for CT's

50% Testing results

(44652 Events in each)

Remaining AG sample (25% of original)

50% Training (12.5% of original)

50% Testing (12.5% of original)

BGE's and AG's tagged and mixed randomly together for both Training and Testing

This leaves to few events to do much more then explore BGE Rejection problem areas.

(i.e. 5629 AG's in each)

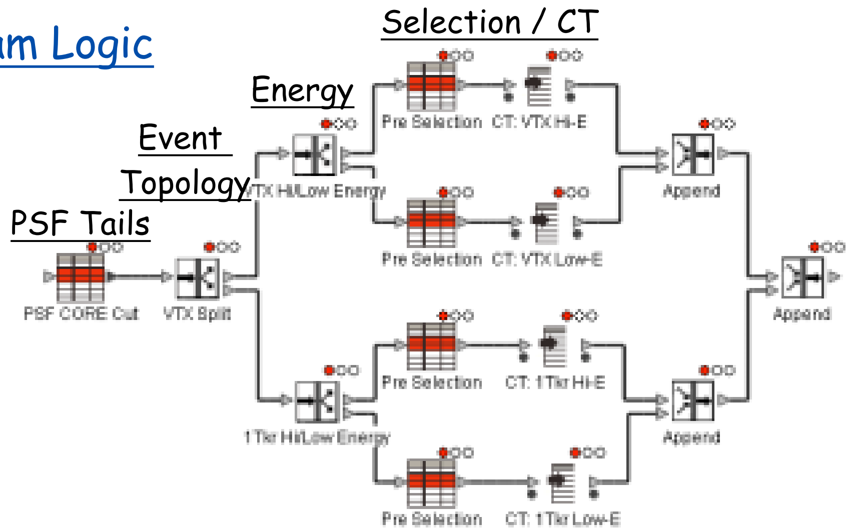
Background Rejection Program

Events with a found VTX have much less background

Large energy dependence suggests subdividing into Low/Hi branches

Large rejection Variables used in Pre Selections

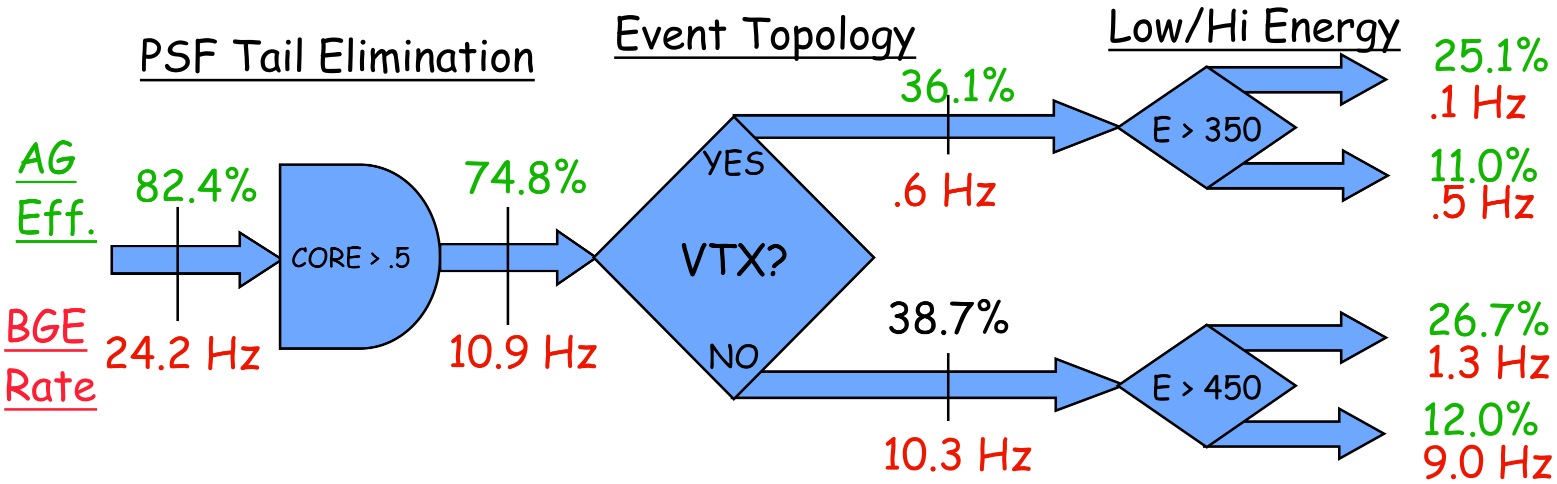
Program Logic


Selection / CT

Energy

Event Topology

PSF Tails


PSF Tail Elimination

Event Topology

Low/Hi Energy

AG Eff.

BGE Rate

82.4%

24.2 Hz

CORE > .5

74.8%

10.9 Hz

VTX?

YES

NO

36.1%

.6 Hz

38.7%

10.3 Hz

E > 350

E > 450

25.1%
.1 Hz

11.0%
.5 Hz

26.7%
1.3 Hz

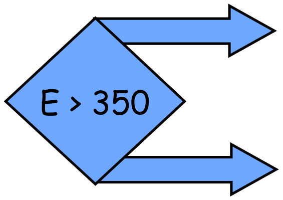
12.0%
9.0 Hz

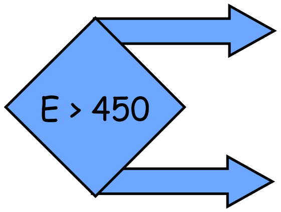
Background Rejection Program - Pre Selection

AG Eff.

BGE Rate

Low/Hi Energy





Low/Hi Energy	Pre Selection Cuts		Out of
25.1% .1 Hz	EvtTkrEComptonRatio > .60 & CalMIPDiff > 60.	23.2% .04 Hz	27.4% (84.7%)
11.0% .5 Hz	AcdTileCount == 0 & CalMIPDiff > -125 & EvtTkrEComptonRatio > .80	8.4% .08 Hz	20.7% (40.6%)
26.7% 1.3 Hz	AcdTotalEnergy < 6.0 & EvtTkrComptonRatio > .70 & CalMIPDiff > 80. & CalLRmsRatio < 20.	23.1% .26 Hz	27.8% (83.1%)
12.0% 9.0 Hz	AcdTileCount == 0 & EvtTkrComptonRatio > 1. & CalLRmsRatio > 5. & Tkr1FirstLayer != 0 & Tkr1FirstLayer < 15	5.5% .25 Hz	24.3% (22.6%)

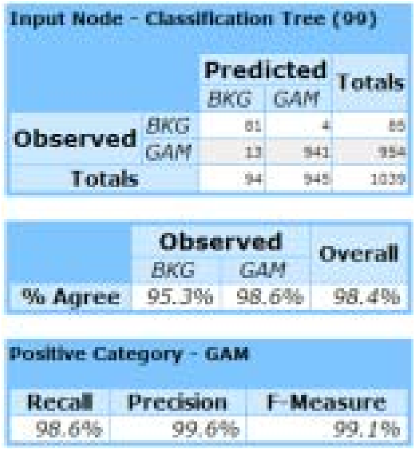
% in Blue show Rel. Eff. to Event Sample in that Branch

6828 AG's to start with.

Background Rejection Program - CT's

VTX & Hi-E Case

Training Sample



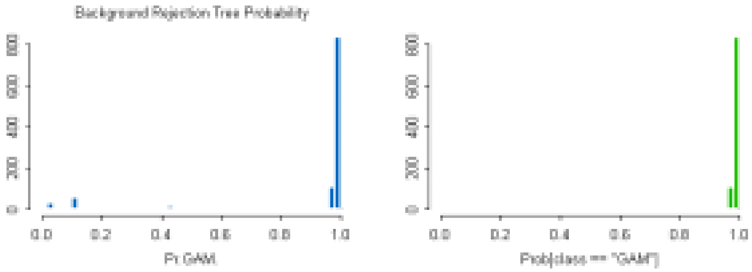
Input Node - Classification Tree (99)

		Predicted		Totals
		BKG	GAM	
Observed	BKG	81	4	85
	GAM	13	941	954
Totals		94	945	1039

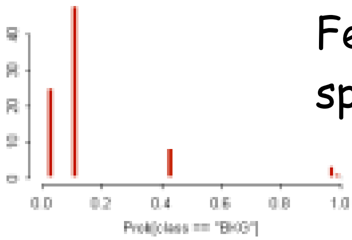
	Observed		Overall
	BKG	GAM	
% Agree	95.3%	98.6%	98.4%

Positive Category - GAM

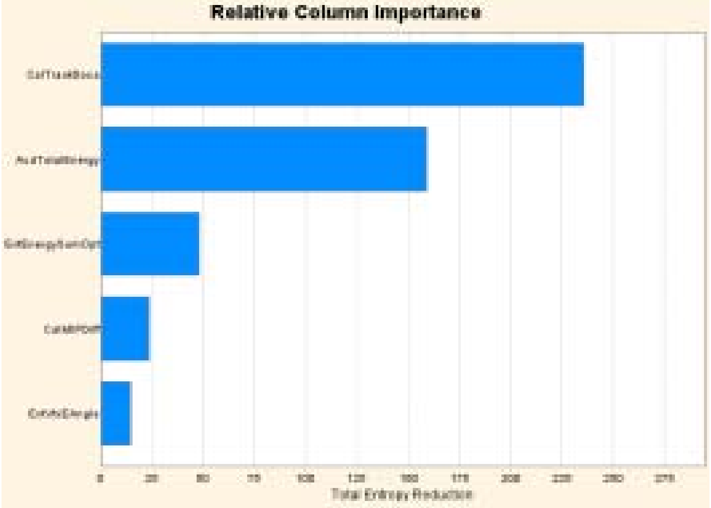
Recall	Precision	F-Measure
98.6%	99.6%	99.1%



Note the lack of events!



Few Events results in sparse CT Trees

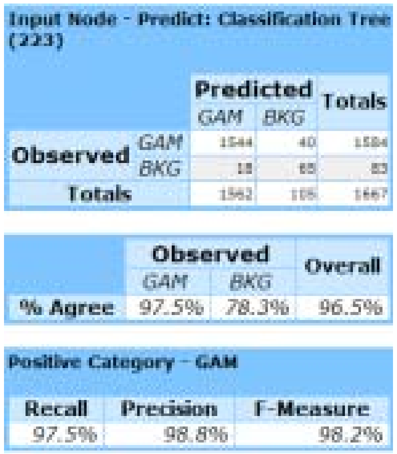


Testing Results

Retention:

AG: 97.5%

BGE: 22.%



Input Node - Predict: Classification Tree (223)

		Predicted		Totals
		GAM	BKG	
Observed	GAM	1544	40	1584
	BKG	18	65	83
Totals		1562	105	1667

	Observed		Overall
	GAM	BKG	
% Agree	97.5%	78.3%	96.5%

Positive Category - GAM

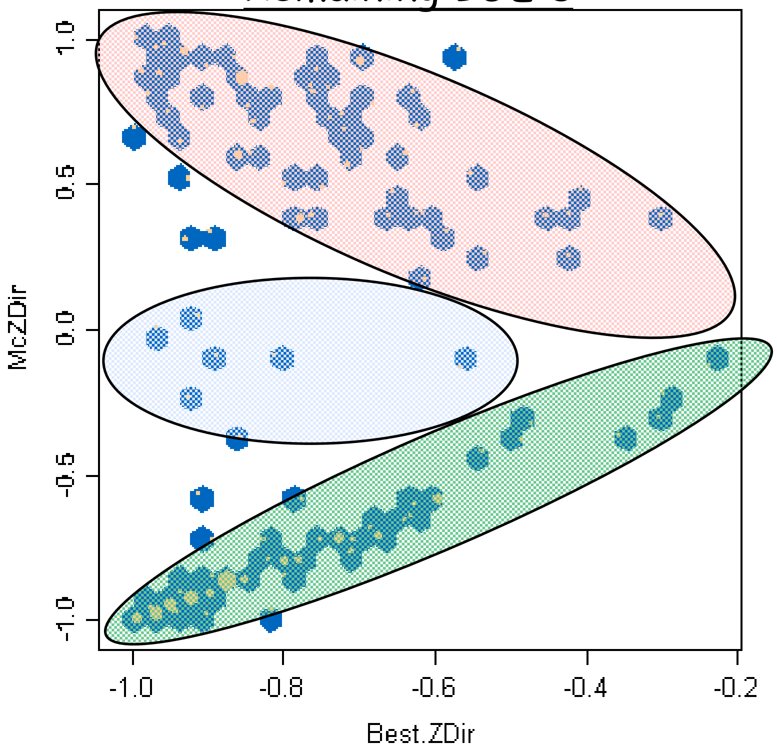
Recall	Precision	F-Measure
97.5%	98.8%	98.2%

Background Rejection Program - CT Results

	Case	CT Tree Disc.		Out of
23.2% .04 Hz	Hi- E	Prob.Gam > .5	22.6% .01 Hz	27.4% (82.5%)
	VTX (350 MeV)			
8.4% .08 Hz	Low- E	Prob.Gam > .9	5.0% .02 Hz	20.7% (24.2%)
23.1% .26 Hz	Hi- E	Prob.Gam > .5	21.5% .02 Hz	27.8% (77.3%)
	1Tkr (450 MeV)			
5.5% .25 Hz	Low- E	Prob.Gam > .9	1.8% .02 Hz	24.3% (7.4%)

Background Rejection Program - What's Left?

Remaining BGE's



A_{eff} & BGE Rate:

A_{eff} = 8400 cm^2 on Axis (E > 3 GeV)

A_{eff} x $\Delta\Omega$ = 2.0 m^2-str

BUT....

BGE Rate 5X too high

3 Classes of BGE Events Remain:

1) 1:1 Correlated Events - ACD Leakage and inefficiency (.04 Hz)

2) 1: -1 Correlated Events - Range-outs from below (.025 Hz)

3) Events at McZDir ~ 0 - Horizontal Events (.005 Hz)

Elimination Strategy

1) ACD Leakage
   - Events found accurately;
   - Small phase space
   - Track projection to ACD cracks

2) Range-outs - MIP Identification in CAL

3) Horizontal Events - Edge CAL hits

Back to CT Basics

CT Tree Generation Mechanism:

Variable Selection: $$\left| \frac{\langle good \rangle - \langle bad \rangle}{\sqrt{\sigma_{good}^2 + \sigma_{bad}^2}} \right|$$

This is a FIRST ORDER TECHNIQUE

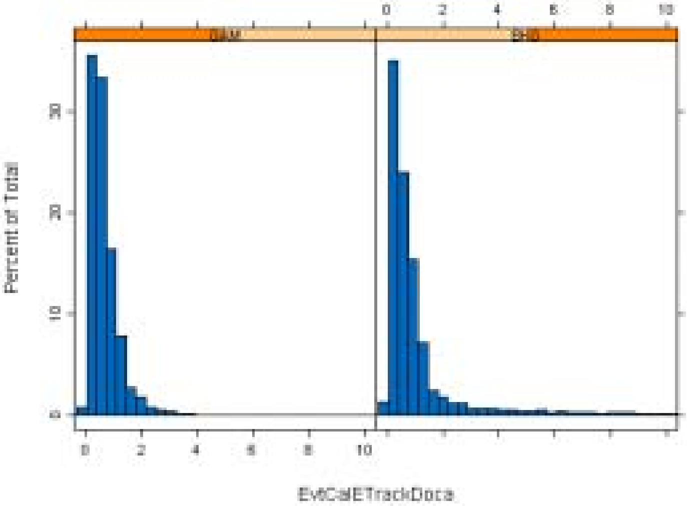
When MEANS are approx. equal it fails!

This is the case for MOST OF GL

Example:

One of the most useful
separation variables:
Energy compensated
Cal-Centroid - Track distance

Means similar - Tails dissimilar



A New CT Mechanism

1. Characterize Distribution extents (tails) by Quantiles

   Example: 95% containment PSF is the 95th Quantile of the PSF distribution

   Alternative Variable Selection:

   Q(Good, 95) - Q(Bad, 95) or - normalized... $\left|\dfrac{Q(Good,95)-Q(Bad,95)}{\sqrt{\sigma_{Good}\cdot\sigma_{Bad}}}\right|$

   Use Generic $N\cdot\log(N)$ for cut placement.

2. CT Generation is a "one step look ahead" - extend to 2,3, etc. steps

3. More Advanced CT Technologies - Ensembles, Boosted Trees, etc.

Iteration #6: *Charm!*

1. Switch over to Onboard Flight Software Filter for "pruning"

Look Ahead:

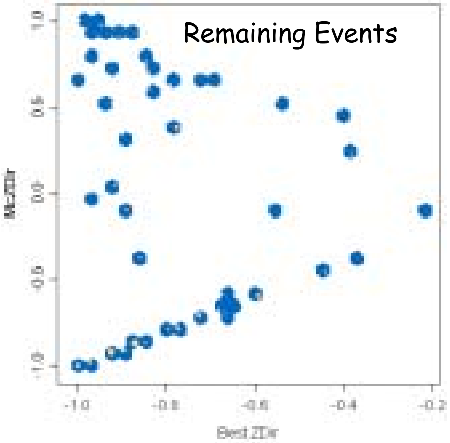
Refiltered Events using FSW Filter *MINUS* bit #17 ("No Tracks")

Kills - 3% of AG sample

(Leaves A_{eff} ~ 8000 cm^2 (E > 3 GeV)

and A_{eff} x $\Delta\Omega$ = 1.9 m^2-str)

Kills - 60% of BGE sample (Rate: .03 Hz)



2. Run at least 5X more events! In fact we should consider simply starting a regular MC production regime rather then the current "one-off" approach

3. Explore alternative Variable Selection Mechanisms.

Conclusions

- Not there yet....

- CT/RT Technology Promising

- Need to condense various choices into data set(s) suitable for public consumption!